

interference and cost, only a portion of the frequencies available in a particular environment are used by any particular base station transceiver. For example, in one embodiment, four pairs of uplink and downlink frequencies are to be used by each base station transceiver. It should be noted that in other standards, such as the TD-SCDMA standard, one frequency is used for both uplink and downlink communications.

[0057] In a GSM environment, signals may be communicated in different frequencies over a period of time, which is divided into frames that are each divided into eight time slots, or channels. Each time slot, or channel, is either a control channel or a traffic channel. Control channels are operable to carry control signals and/or signaling or paging signals, while traffic channels are operable to carry voice and/or other data signals. In the GSM standard, one of the eight channels in a particular frequency, which may be referred to hereinafter as the control frequency, is designated as the control channel. The remaining channels in the control frequency may be traffic channels operable to carry conversations. The control frequency thus consists of one control channel and seven traffic channels. Each remaining frequency may be referred to as a traffic frequency consisting of eight traffic channels. Generally, each traffic channel can support one conversation or other communication in full rate, two conversations or other communications in half rate, or an unlimited number of conversations or other communications in GPRS or group mode.

[0058] When a particular mobile station 15 is engaged in a call, voice and/or other data signals intended for that mobile station 15 are transmitted from base station system 12 via smart antenna array 28 within a particular traffic channel (or time slot) in a particular frequency. The mobile station 15 will "listen" for the voice and/or data signals only in the particular traffic channel in the particular frequency. Thus, mobile station 15 must know when, and at which frequency, to "listen" for the voice signals, and thus must be synchronized to base station transceiver 24.

[0059] Smart antenna apparatus 16 must also be synchronized with base station transceiver 24 in order to operate properly. For example, smart antenna apparatus 16 must be synchronized with base station transceiver 24 in order to perform its beam-switching functions as discussed above. Further, in some embodiments, smart antenna apparatus 16 should be synchronized with base station 12 more accurately than mobile station 15 is synchronized with base station 12. The synchronization of smart antenna apparatus 16 with base station 12 is discussed in greater detail below with reference to FIGS. 5 through 8.

[0060] FIG. 2 illustrates the general architecture and operation of smart antenna system 14. As discussed above, smart antenna system 14 includes smart antenna apparatus 16 and antenna unit 18. Smart antenna apparatus 16 includes a receiving system 100, a processing system 102, a storage system 103, a control channel monitoring module 104, and a signaling information monitoring system 106. In some embodiments, smart antenna apparatus 16 also includes one or more diplexers, such as diplexers 120 and 122.

[0061] Receiving system 100 is generally operable to receive radio signals communicated from mobile stations 15. In particular, receiving system 100 may receive analog radio signals communicated from mobile stations 15,

received at antenna unit 18, and communicated to receiving system 100 via paths 150 and 152. Receiving system 100 may be further operable to convert the analog radio signals to digital signals and communicate the digital signals to processing system 102.

[0062] As shown in FIG. 3, receiving system 100 may include one or more frequency receiver units 108, each corresponding with a particular frequency (in other words, a frequency band) and thus operable to receive signals communicated by mobile stations 15 via that frequency. Each frequency receiver unit 108 may include one or more beam receivers 112 operable to receive signals communicated in a particular frequency. Each frequency receiver unit 108 may include a beam receiver 112 corresponding with each narrow beam 34. For example, in one embodiment in which smart antenna system 14 divides wide beam 32 into seven narrow beams 34, each frequency receiver unit 108 includes eight beam receivers 112, one for each of the seven narrow beams 34 and one for wide beam 32, which is received by sector antenna 31. Beam receivers 112 may be operable to convert received radio frequency signals into baseband signals. In a particular embodiment, the beam receivers 112 are identical to each other.

[0063] Receiving system 100 may also include one or more samplers 116 operable to convert signals from analog to digital. In particular, one or more samplers 116 may convert analog signals received by each beam receiver 112 to digital signals such that the signals may be processed by processing system 102.

[0064] Referring again to FIG. 2, processing system 102 is generally operable to perform beam-selection functions. In particular, processing system 102 may execute one or more algorithms based on various inputs and/or parameters to determine a transmitting beam selection 124 and a receiving beam selection 126. In other words, processing system 102 is operable to select one of the narrow beams 34 to communicate signals received by antenna unit 18 to base station transceiver 24, and one of the narrow beams 34 (which may be the same or a different narrow beam 34) to transmit downlink signals to mobile stations 15.

[0065] As shown in FIG. 4, processing system 102 may include one or more processing modules 62 operable to process received signals, such as signaling signals, control signals, and/or traffic signals. In some embodiments, processing system 102 includes one processing module 62 for each frequency used by smart antenna system 14. Thus, each processing module 62 may process signals communicated in one of the frequencies used by base station transceiver 24. Each processing module 62 is generally operable to perform one or more functions, including beam-selection functions. In an environment using time division multiplexing, such as a GSM environment, each processing module 62 may be operable to determine both uplink and downlink beam selections for communicating signals in each time slot. Thus, in some embodiments, each processing module 62 is operable to determine both uplink and downlink beam selections for each time slot in a particular frequency.

[0066] Processing modules 62 may make beam selection decisions based on one or more inputs or parameters, including signals received from receiving system 100 and/or signaling information received from signaling information monitoring system 106. For example, each processing mod-